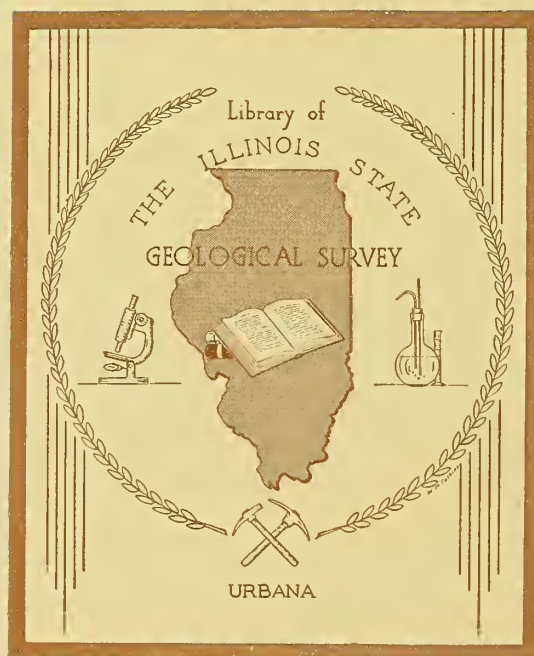
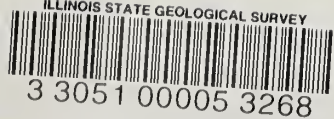




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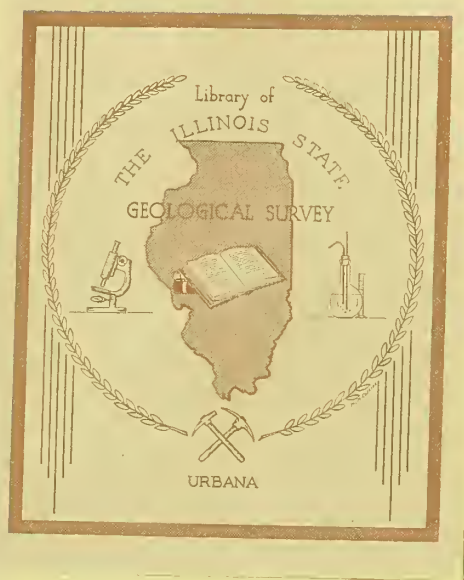
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GEOLOGIC FACTORS
IN COMMUNITY DEVELOPMENT
AT NAPERVILLE, ILLINOIS

JAMES E. HACKETT

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GEOLOGIC FACTORS IN COMMUNITY DEVELOPMENT AT NAPERVILLE, ILLINOIS

James E. Hackett

INTRODUCTION

The role of the physical environment in the development of an expanding community was emphasized by a recent planning study for the city of Naperville, Illinois. The study was conducted by a citizens' committee of the Naperville Community Council (Osborne et al., 1966). The physical environment includes subsurface conditions as well as the more obvious topography and drainage. Therefore, as a member of the committee and representative of the Illinois State Geological Survey, I compiled information on the geology, ground-water resources, stream flow, and extent of flooding and related the data to various aspects of community development.

The close relation that became evident between geologic factors and the physical aspects of community development strongly influenced the conclusions and recommendations of the planning study. The basic aspects of these relations are presented here to exemplify the value of considering geologic factors in community planning studies.

Community Trends

Naperville is in southwestern DuPage County, approximately 35 miles west of Chicago (fig. 1). Population has grown steadily from 12,933 in 1960 (U. S. Census Bur., 1963) to 18,734 in 1966 (Del Hosler, City Clerk, Naperville, Ill., personal communication). Associated with this growth has been the physical expansion of the city by incorporation of tracts of land for subdivisions and for industrial and commercial uses, which, in turn, has resulted in expansion of community service facilities for water, sewage disposal, and storm-water drainage control.

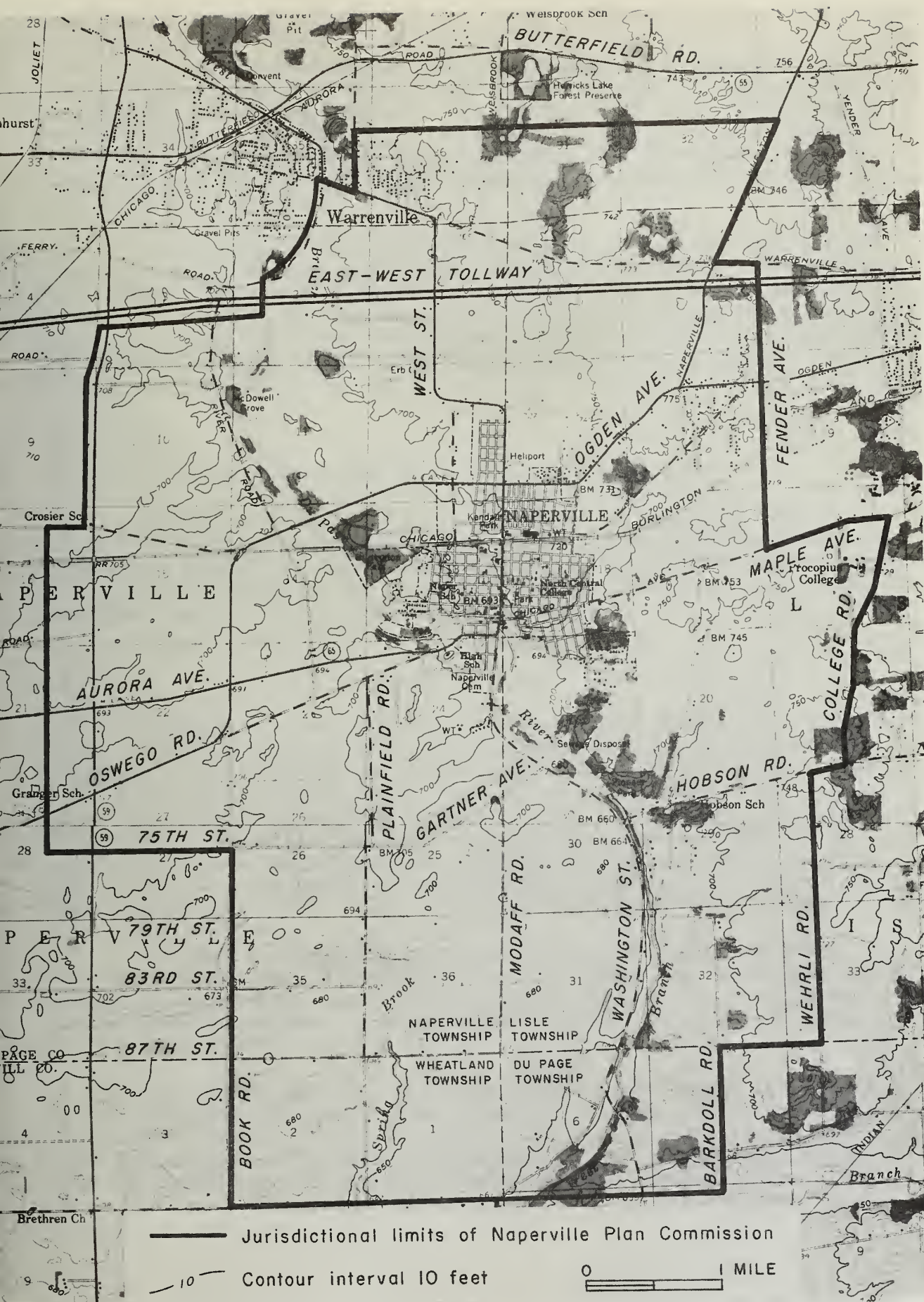


Fig. 1 - Topography, geography, and culture of Naperville area. From U. S. Geological Survey topographic maps of Wheaton and Joliet Quadrangles (1954).



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As projections indicate a probable population of 60,000 by the year 1985 (Bartholomew and Assoc., 1961), continued physical expansion of the community can also be expected. Naperville differs from communities in the metropolitan area whose corporate boundaries abut those of an adjacent community on one or more sides, for unurbanized land is available on all sides of Naperville that will permit development to proceed in about the same manner as at present.

This fortunate situation provides the city with opportunity for selecting a growth pattern suited to its physical environment. Development that is discordant with the physical environment results in problems that are both inconvenient and expensive to individuals as well as to the municipality. In addition to hazards inherent in the physical setting, there are also benefits that can either be utilized or negated by the manner in which land is used.

PHYSICAL CHARACTERISTICS OF THE NAPERVILLE AREA

The physical characteristics considered in this study include the nature of the streams and rivers that drain the surface, the characteristics of slope and relief that determine the landscape, the deposits of clay, gravel, and rock that underlie the surface of the land, and the sources of ground water that supply the water needs of the community.

General Setting

Naperville is situated along the West Branch DuPage River, which begins in northern DuPage County near the DuPage-Cook county line and flows from north to south through the western part of the county (fig. 1). Naperville is the county's southernmost community along the river. North of and upstream from the city are Warrenville, Winfield, West Chicago, and Wheaton. The West Branch joins the East Branch immediately south of the DuPage-Will county line to form the DuPage River. The boundary of the Naperville Plan Commission Area of Jurisdiction, hereafter called the Naperville area, includes a small part of the valley of the East Branch near this junction.

The West Branch occupies a shallow valley only slightly below gently rolling uplands. Throughout most of its course the river flows on sand and gravel or pebbly clay. At Naperville, however, the deposits of clay and gravel are thinner than elsewhere along the valley and the river flows on solid rock at some places.

The general features of the land surface were formed by glaciers that occupied this area some 12,000 to 15,000 years ago. The melting glacial ice left behind a residue of pebbly clay, and the streams of glacial meltwater that issued from the ice deposited sand and gravel. These materials are underlain at various depths by sedimentary bedrock—shale, sandstone, limestone, and dolomite—that extends to the granite basement at a depth of more than 4000 feet.

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Slope and Relief

The land surface has many of the features that characterize glaciated areas. It is an irregular surface containing many knobs and depressions (fig. 1), and total relief (the difference in elevation from the lowest to highest point) in the Naperville area is only 180 feet. In spite of its irregularity, local relief is only slight to moderate. As the natural surface drainage is poorly developed, the many slight depressions present on the upland are poorly drained and tend to retain pools of water for long periods after heavy rain or snowmelt.

Land slopes are gentle, not exceeding 10 percent (a 10-foot rise in elevation per 100 feet of distance) in most of the area. Moderate to steep slopes are rare and are usually restricted to the margins of the major valleys. The steep slopes are almost all east of the West Branch (fig. 1).

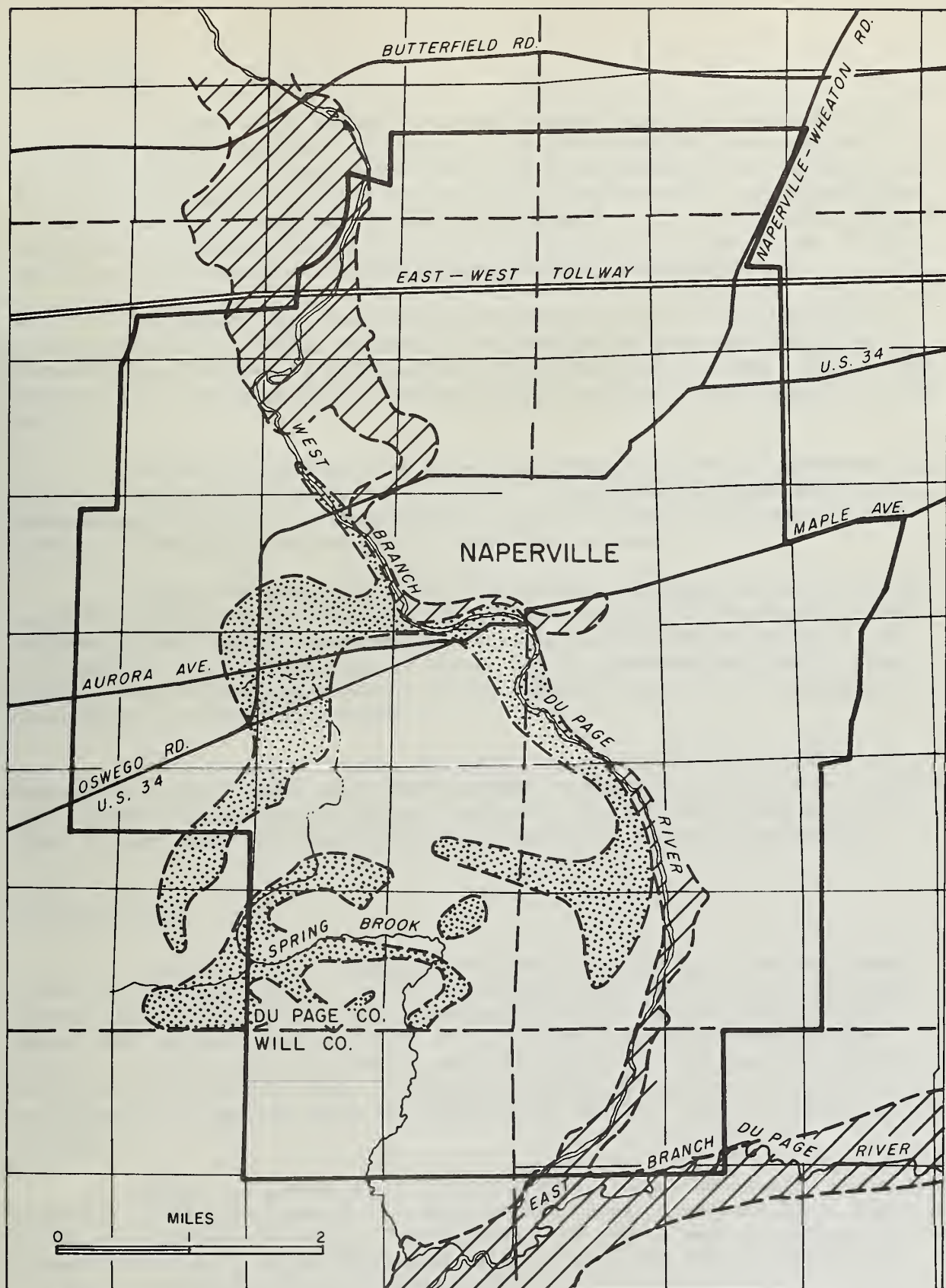
Drainage and Stream Flow

The West Branch DuPage River and Spring Brook are the principal streams in the Naperville area. The East Branch DuPage River crosses the extreme southeastern part of the area. Spring Brook, a small tributary to the DuPage River, drains an area of about 12 square miles. The West Branch has a drainage area of approximately 120 square miles.

According to flow-duration curves presented in the water resource planning study for the metropolitan area (Sheaffer and Zeizel, 1966, p. 20, fig. 9), average flow in the West Branch DuPage River is approximately 50 cubic feet per second, but during periods of low flow, normally in August, September, and October, flow is likely to be less than 20 cubic feet per second. Flood flows, or periods of extremely high flows, are characteristically of short duration compared to periods of low flow. According to the U. S. Geological Survey report on floods in the Naperville Quadrangle (Allen and May, 1965), flows of 1800 cubic feet per second and a recurrence interval of 10 years are cited for the West Branch at the Warrenville Road gauge. These figures allow comparison of the differences between flood flow, average flow, and low flow of the West Branch.

The Subsurface

The sequence of earth materials below land surface and the manner in which they are distributed within the area (fig. 2) form the third dimension of the physical setting. Aspects of the subsurface that most directly concern land use and areal development problems in the Naperville area are (1) the character and distribution of pebbly clay, (2) the presence of deposits of sand and gravel at land surface, (3) the occurrence of bedrock at such shallow depths that it may affect construction, and (4) the depth and distribution of units in the bedrock that are sources of water for the community.



- | | |
|---|---|
|  Dolomite bedrock within 20 feet of land surface |  Sand and gravel |
|  Jurisdictional limits of Naperville Plan Commission |  Pebbly clay |

Fig. 2 - Areas underlain by pebbly clay, sand and gravel, and shallow dolomite.

Pebbly Clay

The most common material directly underlying land surface in the Naperville area is glacial pebbly clay. It covers deposits of sand and gravel or bedrock. At some places, especially adjacent to the valley of the West Branch and in areas where bedrock is at shallow depth, the pebbly clay is likely to be so thin that it goes unrecognized. At other places, particularly in the upland areas east of the West Branch, it is more than 75 feet thick and is the dominant material encountered in construction.

The pebbly clay has several characteristics of significance to areal development. First, because it is composed of clay and silt, the permeability (the rate at which water can move through the material) is low. However, it is not impermeable and will permit water to move through it slowly.

Second, the pebbly clay is unconsolidated and can be excavated and moved readily with earth-moving equipment. Occasionally, large rocks or boulders several feet in diameter are found in the clay that might be troublesome to construction, but their occurrence is rare.

Third, the pebbly clay has good bearing strength and usually even heavy structures can be founded on it without problems of settlement. But, because glacial deposits can vary in character within short distances, it is advisable to make test borings before heavy structures are built. The borings would detect the presence of compressible materials that should be considered in foundation designs.

Owing to its strength, the pebbly clay is relatively stable on moderate to steep slopes and is not subject to excessive slumping or sliding. However, care should always be taken in areas of more than six degrees slope to make sure construction will not result in unstable conditions.

Sand and Gravel

Sand and gravel, usually considered as a unit, is another common product of glacial action. In the Naperville area, sand and gravel occurs directly below land surface along the valley of the West Branch. Figure 2 shows areas in which such material is most likely to be present at land surface. In the Naperville area, sand and gravel also may occur buried beneath a cover of pebbly clay. The depth to sand and gravel varies, but it is generally at shallow depth in valley areas and more deeply buried in the uplands.

Unlike the pebbly clay, sand and gravel deposits usually are quite permeable. There is, however, a considerable range in permeability, even within an individual deposit. Because sand and gravel has the ability to transmit water at a relatively rapid rate, it presents both benefits and hazards for land use and areal development.

Areas underlain by sand and gravel are subject to rapid infiltration of rain and snowmelt; ponding of surface water in these areas is

uncommon. Where sand and gravel deposits are sufficiently thick, have a high permeability, and are deep enough to be water saturated, they are a valuable source of water supply to wells. On the other hand, sand and gravel tends to be highly unstable when saturated and will move rapidly into any hole or excavation that penetrates it. Leakage into underground facilities can thus be a serious problem unless the construction is extensively water-proofed or the deposit permanently dewatered.

Sand and gravel also is a valuable mineral resource. The resource potential of a deposit is determined by its quality, volume, and accessibility. Extensive gravel operations at Warrenville indicate that the deposits along the West Branch in Naperville are a potential mineral resource.

Bedrock

The thick sequence of rocks that underlies the Naperville area also affects land use and community development. The uppermost unit of the bedrock is a hard dolomite. An abandoned quarry in this dolomite was developed into the Centennial Beach community swimming pool.

The dolomite underlies all of the Naperville area but is generally covered by relatively thick glacial deposits. Part of the buried rock surface was the land surface before the glaciers advanced across this region; part of it was carved by the glacial ice itself. The bedrock occurs at shallower depth in some parts of the Naperville area than in others. Figure 2 shows areas in which dolomite bedrock is likely to occur within 20 feet of the surface.

The dolomite has an extremely high bearing strength. Because of its hardness, excavations into the rock usually require drilling and blasting. Occasionally, solution cavities with a filling of weaker clay are found extending downward from the upper surface of the bedrock. Although this condition appears to be rare at Naperville, test boring to establish the suitability of the rock for foundations is advisable before heavy buildings are constructed.

In the past, the dolomite was quarried extensively for building stone. Now its principal use is as a source of crushed aggregate for construction materials.

Although the dolomite is not in itself very permeable, it commonly contains cracks or narrow openings through which water moves readily. Because of this characteristic it is widely used as a source of water. The distribution of these openings is generally random and unpredictable.

Underlying the dolomite are other bedrock units of shale, dolomite, and sandstone. Because of their importance to water supplies, the sandstone units have a special significance for area development. Within the bedrock sequence at Naperville are three major sandstones—the St. Peter Sandstone about 600 to 900 feet below land surface, the Ironton-Galesville Sandstone at a depth of about 1200 to 1500 feet, and the Mt. Simon Sandstone below a depth of about 1800 feet.

PHYSICAL ASPECTS OF DEVELOPMENT

Construction

Construction of residential, industrial, and commercial buildings should be preceded by a study of the flooding potential of the site, its drainage, slope, and relief, the excavation characteristics of the subsurface deposits, and the suitability of those deposits for foundations.

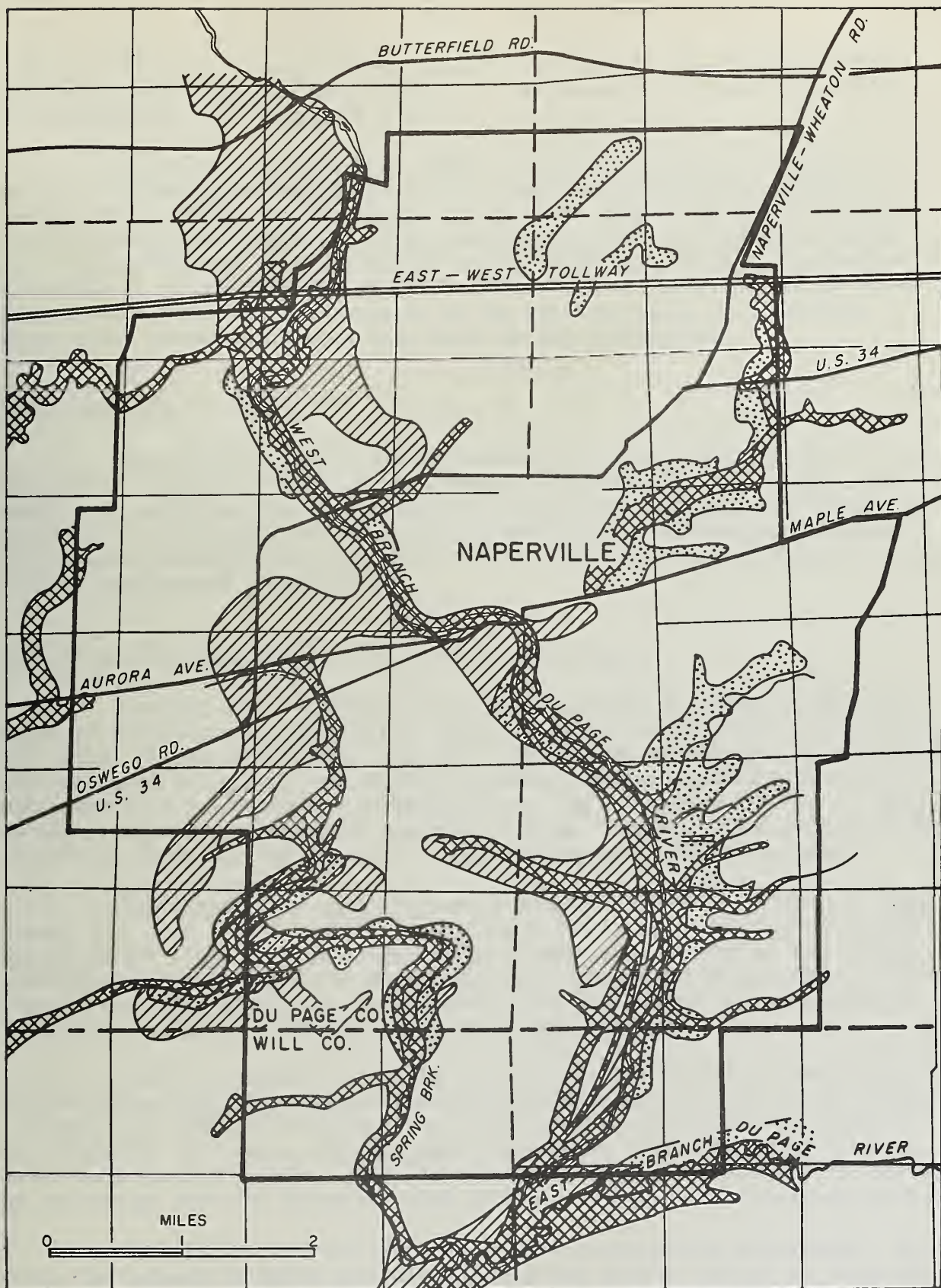
Flooding and Drainage

Construction in areas subject to flooding or in areas where inadequate drainage results from poorly planned community development presents probably the most serious problems related to the physical environment. Flooding is usually a localized problem, but the problem of adequate drainage extends outside the confines of the individual development and affects other areas of the community.

The areas affected by past flooding within the Naperville area are shown in figure 3. The pattern of formerly flooded areas is taken from maps of the Naperville, Wheaton, Normantown, and Romeoville Quadrangles published by the U. S. Geological Survey (Allen and May, 1965; May and Allen, 1965; May, 1967; Noehre and Walter, 1965). Because of the low relief, gentle land slopes, and the small surface drainageways, flooding occurs on a limited scale, but it is widely distributed throughout the region rather than being concentrated in any one area. Flooding occurs in both valleys and uplands. Because the floodplains of the rivers are relatively narrow, valley flooding does not affect wide areas of land.

Flooding on upland areas away from well defined valleys is a consequence of the irregular topography and the immature development of natural drainage. At times of heavy rainfall or thaw, surface runoff is directed toward depressions that become ponded. Because most of the upland area is underlain by relatively tight pebbly clay, downward seepage, or infiltration, is very slow and water tends to remain at land surface for long periods.

Where depressions are small, drainage can be improved by filling or by installation of drain tiles and storm-water drains. Although these procedures will normally solve the drainage problem on the development site, they will also result in the more rapid movement of water into the valleys during periods of high runoff. The quantity of water per unit of time carried in the downstream portions of the natural drainageways will thereby be increased. When, as is sometimes the case in Naperville, new developments are opened upstream from older ones that are in or across natural drainage channels, any flooding or drainage control problems that might exist in the older development are intensified. Solution of the problem often requires the collection and storage of storm water in retention basins, either on the site of the new development or at some location upstream from existing developments. Establishment of a retention basin requires either that the developer set aside part of the acreage he wishes to develop, that he



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|  Steep slopes. Low-density construction or open space use |  Subject to flooding. Open space use |
|  Limiting subsurface conditions. Subsurface study advised before construction |  Jurisdictional limits of Naperville Plan Commission |

Fig. 3 - Physical conditions affecting land use.

acquire adjoining open land downstream for such use, or that public land be provided in the watershed for storage of the excess storm water that existing drainage facilities cannot handle.

Hydrologic studies have shown that urban development increases the amount of storm-water runoff and thereby increases flood-water levels in those areas. In the Naperville area where there is poor natural drainage, drainage facilities installed during land development are likely to result in a high percentage of increase in runoff. Such drainage problems can be minimized if proper drainage control is exercised by judicious use of retention ponds and basins, particularly in the upstream parts of watersheds where older developments have been built in the drainageway.

Slope and Relief

Topographic limitations or hazards to building are not great in the Naperville area because slopes are relatively gentle (fig. 3). Level topography is a definite advantage in development of residential subdivisions with small lots. It permits street layout without regard to topography, allows the maximum number of lots per unit of area, and requires a minimum of cut-and-fill in subdivision construction.

Excavation Characteristics and Foundation Conditions

Lowland areas underlain by sand and gravel are likely to be saturated at relatively shallow depths, especially, in the Naperville area, along the valley of the West Branch (fig. 2). Excavations extending into saturated silt and sand and gravel may require extensive shoring or dewatering to permit construction. Basements extending below the saturation level are likely to have continuous problems of excessive seepage because of the high permeability of the materials and the lack of opportunity for gravity drainage.

Installation of sanitary sewers presents a special problem in such areas. Not only is the cost of installation likely to be high, but, unless special water-tight materials are used, the mains are likely to drain large quantities of water and seriously overload the sewage treatment plant. Construction in low-lying areas underlain by sand and gravel should be preceded by test boring to establish depth to water saturation.

Dolomite bedrock is likely to occur within 20 feet of land surface in some areas (fig. 2). Excavation into dolomite usually requires drilling or blasting. Special design and construction of storm and sanitary sewers that function by gravity flow are often necessary. Water-tight sanitary sewer construction is also advisable because leakage can result in the spread of raw sewage into the dolomite, with little attenuation by filtering action.

The shallow bedrock also has certain construction advantages. Areas where the bedrock is below excavation depths but shallow enough to allow advantage to be taken of its high bearing strength are ideal locations for heavy structures.

Open Space Uses

Open space uses include parks, recreational areas, and undeveloped open areas. These have the least physical restrictions of all land uses involved in community development. They can be developed in areas that are subject to flooding or that must be left open for drainage control. Open spaces also can be developed in areas that have special significance for resource conservation. For instance, they may be set aside for recharging underground water sources or because they contain usable mineral resources.

General Community Development

Some aspects of the physical environment that strongly affect community development cannot be considered in terms of specific land uses alone. Because the problems are regional in character they are seldom solvable on a local land use basis, but they can affect and be affected by the land use patterns of the community. Water quality considerations fall in this category, as does water supply. Both relate directly to the health and welfare of the community in general. Both are largely a function of the characteristics of the physical environment.

Water Quality Considerations

The quality of the water in the West Branch at Naperville is not merely a local problem but is the consequence of the degree of development and the waste disposal practices of all communities that occupy the watershed upstream. At Naperville this is a special problem, for it is at the downstream end of the drainage basin in the county. Unlike West Chicago and Wheaton, the other major communities in the West Branch basin, Naperville has the river flowing through its center.

The West Branch is similar to other drainageways that serve the metropolitan area communities in northeastern Illinois in that it is a small stream of low flow and has a limited capacity to assimilate the waste materials produced by the communities and associated industries along it. The waste dilution capacity of these drainageways is commonly exceeded by the waste loads produced by highly concentrated developments in the basins. Not only does this result in a reduction in the recreational facilities afforded by the stream, but it can produce a health hazard and offensive odors, particularly in late summer when stream flow is low. A West Branch of good water quality is a definite benefit to the city; a highly polluted stream would be a serious detriment.

The quality of water in the West Branch affects the community in another respect. The degree of treatment of waste required of the treatment plant is determined by the quantity of dilution water available during periods of low flow. That more stringent water quality standards are anticipated at both state and federal levels in the near future, that the amount of dilution water available at low flow is limited, and that increased development of the watershed upstream from Naperville is inevitable, all indicate that the community can look forward to increasing costs and problems of waste

disposal as the city expands. Care should be taken that abnormally high waste-producing elements are not introduced during development.

The effects of waste disposal on patterns of community development must also be taken into account. Intensive residential and industrial development on the upstream side of the city would require expansion of sewage treatment facilities at a location where the effluent from these facilities would be directed through the major part of the community. Expansion to the south would have the advantage of directing the location of additional treatment plants downstream from the city proper and toward areas where increased stream flow would provide additional dilution capacity.

Water Supply Considerations

There is little possibility that surface water reservoirs of sufficient size to serve the needs of the Naperville community will be developed because valleys are shallow and there is generally low relief in the area. In addition, the low flow of the streams would not be adequate to provide both water supply and dilution water.

Importation would be a possible means of acquiring additional supplies of water in the future. However, the most logical source of imported water is Lake Michigan, and the serious legal problems involved make it an unlikely answer to the water supply problem.

Naperville must be considered dependent upon the supplies of water available from underground sources for present and future community needs. These supplies are available from sand and gravel deposits, the dolomite bedrock, and from deep sandstones (fig. 4).

Naperville at present obtains water mainly from 4 wells in the dolomite bedrock and one deep well in the sandstones. Total pumpage from these wells averages nearly 1.5 million gallons a day, about 75 gallons per capita. Per capita water use in DuPage County in 1960 was 80 gallons per day. For future planning purposes, anticipating increases in industrial use as a result of expansion, a figure of 100 gallons per day per person is often cited. According to these figures, a projected population of 60,000 in 1980 would require from 4.5 to 6 million gallons per day.

Studies of the ground-water resources of DuPage County and northeastern Illinois by state and metropolitan area agencies have indicated that water supplies in the Naperville area are sufficient to supply needs in the near future (Zeizel et al., 1962; Suter et al., 1959). However, these studies have also indicated that rates of natural recharge of the water sources are limited and that future growth could exceed the capability of the system to provide the required water on a sustaining basis. The sustained yield of present pumping centers in the Naperville-Eola area is 2.6 million gallons per day. Spreading the pumping centers over a larger area could add to this figure.

No studies to assess the specific extent of the ground-water resources of the Naperville area have been made. The resource evaluation figures presented were based on consideration of the dolomite bedrock as the

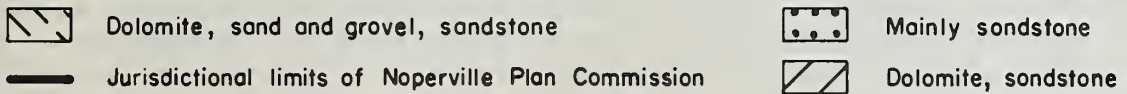
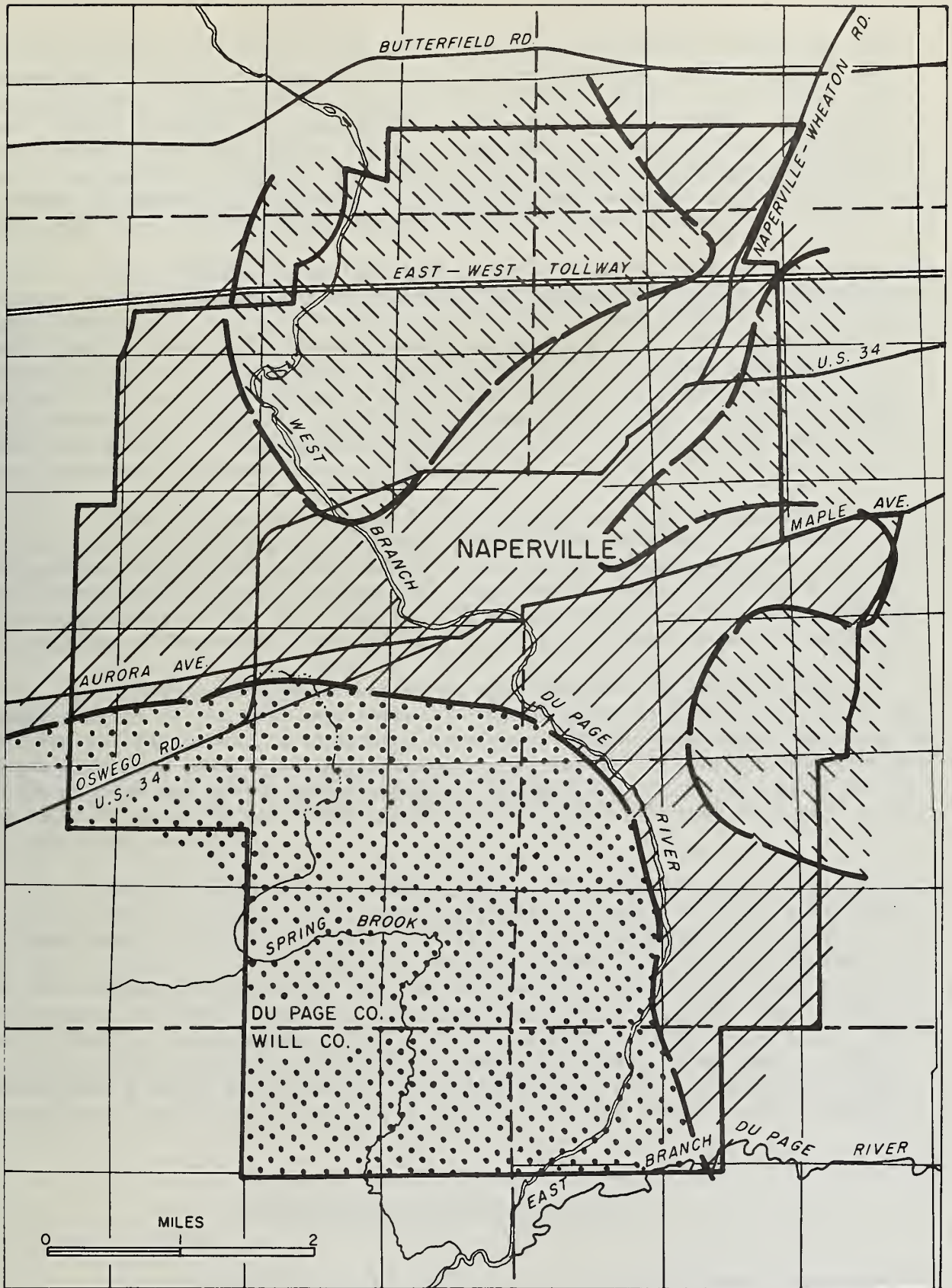


Fig. 4 - Underground water sources for municipal wells.

principal source of water. Additional supplies are available from the deep sandstones, but these sources are largely overdeveloped in the Chicago metropolitan area (Suter et al., 1959; Zeizel et al., 1962). As a result, the water level in wells in these units can be expected to decline. Because of their depth, sandstone wells are more expensive to construct and the pumping costs are greater. Depth to water in sandstone wells at Naperville is at present in excess of 450 feet. Nevertheless, use of water from the sandstones may prove to be expedient as the community continues to grow.

The sandstones are likely to be relatively consistent in production, whereas the productivity of the dolomite is extremely variable. According to maps presented by Suter et al. (1959) and Zeizel et al. (1962), the productivity of wells into the dolomite bedrock can be expected to be lower in the southwestern part of the Naperville area than in the northern and eastern parts of the area. Development in the southwestern area may, therefore, be accompanied by problems of obtaining satisfactory yields from wells drilled into the dolomite. Consideration should be given to obtaining water supplies from the deep sandstones rather than from the dolomite.

The yield of the sand and gravel deposits in the Naperville area is not known, as no municipal wells have been drilled into these materials. Subsurface information available indicates that promising deposits are present, particularly in the northern and southeastern parts of the area and along the valley of the West Branch. The possibility of using these deposits to supplement the water resources of the Naperville area should be explored.

Possible sources of water are most numerous in the northern and eastern parts of the area and fewest in the southwestern part (fig. 4). The pattern is significant to community development because it shows the areas in which alternate sources of water present opportunity to consider relative benefits of cost and productivity and also designates areas in which the manner of land use could affect water quality or the water resource potential of existing water sources.

Water obtained from underground sources in the Naperville area has a high chemical content, being especially high in lime, and as a consequence is very hard—400 to 500 parts per million total dissolved solids (Zeizel et al., 1962, p. 77). The water is normally free of bacterial pollutants and is less subject to pollution than are the surface waters. However, precautions must be taken to protect the underground water supplies from pollution as a result of land-use practices. On-site disposal of waste products, including individual septic disposal systems, should be discouraged, as they constitute a potential threat to the potability of the only source of water supply that can be relied upon to serve the needs of the expanding community.

APPLICATIONS TO LAND USE PLANNING

In planning the use of a land area, physical factors of susceptibility to flooding, the topographic relief, and the subsurface conditions must be considered. In areas known to be subject to periodic flooding, the building of structures for commercial or residential use involves considerable

risks. Adequate flood proofing to protect the building and its interior against the consequences of inundation by flood waters is costly. On flood-plains, use of land for public or private open spaces is recommended.

Areas with slope in excess of 6 percent present problems to small-lot subdivision development and other high-density construction. They increase the cost of development and are more likely to be unstable. These areas are, however, often suitable for low-density construction, such as estate residences, or for open-space uses.

Where it is suspected that subsurface conditions might be unfavorable, subsurface investigations should be conducted prior to construction to establish the limitations needed for the intended use.

In terms of over-all community development, the physical environment can also provide specific benefits. In the northern part of the community, along the valley of the West Branch DuPage River, extensive deposits of sand and gravel suitable for use as construction materials occur, and studies of the subsurface indicate that these deposits extend below the normal river level. In that area certain multiple-use benefits might be realized. Properly controlled excavation of the gravels for commercial use might be followed by development of public recreational lakes or of private lakes for residential estates or industrial parks. The excavations also could be used as storage basins for flood flows or as ground-water recharge pits.

The valley of Spring Brook in the southwestern part of the Naperville area is unusually well suited to development of a surface water reservoir. The Spring Brook site was recognized in a study of forest preserves in DuPage County by the Northeastern Illinois Planning Commission. In that study (NIPC, 1965) it was determined a reservoir with a water depth of about 30 feet could be developed to provide a recreational lake in a region where water-based recreational facilities are at a premium.

Planning policies recognizing the importance of the physical environment were drawn up by the Naperville study group and are summarized below.

1. Construction and open-space uses of the land should be planned in accordance with the existing physical conditions. Regulations controlling development in areas hazardous to building should be written and adopted.

2. Open-space uses, public or private, should be adopted in areas where there are physical hazards to conventional development. Where such physical benefits as drainage control, conservation of needed natural resources, and preservation of unusual aesthetic features are indicated, they should be realized for the community by proper ordinances.

3. The type and pattern of future development should comply with the characteristics of the environment so that adequate stream flow and underground water of satisfactory quality will continue to be available.

4. Underground water should be recognized as the sole dependable source of water available for municipal needs. The type of development and

the nature of land use in the community should be that which is most compatible with proper water-resource conservation and water-management practices.

5. Because the underground water resources have limits, community growth should be evaluated in light of a thoroughly realistic appraisal of the water supply potential of the area and of the means available to insure the most efficient development of an adequate supply of potable water for the future.

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